NASA
Spaceport Engineering and Technology Directorate
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Kennedy Space Center, Florida

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SUBJECT: Failure Analysis of the Multi Mission Support Equipment (MMSE) Cable electrical flashover at the Space Station Processing Facility (SSPF)

CUSTOMER: Jeff J. Heuman (connector) / Boeing / 721C-R210
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1.0 ABSTRACT

The MMSE Transporter Shore Power Cable, C-1 (see Figure 1), experienced an electrical flashover when the Space Station Processing Facility (SSPF) receptacle was initially energized thru breaker S1-E03-039. Several inadequacies in the cable assembly construction, allowed twisting and normal manhandling of the cable assembly (during plug connection to the receptacle) to apply stress to the inside cable conductors which caused them to work loose from their pressure clamp terminations and become free to reposition inside the connector. After closing the circuit breaker, electrical arcing between two conductors was evident, after one came loose. The arcing caused a “flashover” that vaporized part of the loose ground potential wire and caused subsequent damage to the connector assembly. The force of the flashover caused the cable to separate (see Figure 2) from it’s power plug connected to the SSPF wall receptacle.

2.0 FOREWORD

2.1 The cable was 150 feet long and comprised of 2/0 gauge, 3 conductors plus a G-GC type cable ground (see Figure 1). The connector assemblies are a Russel-Stoll (7148R) plug on one end and a Pyle-National (GB-1028-31PL-38) plug [failed component] on the end that was connected to the SSPF wall receptacle. The cable conductors are copper stranded wire, which are individually terminated in the Pyle-National plug terminals by pressure pad screw plates. The cable is secured in the plug body by two methods of retention: 1) a specific sized grommet located just inside the plug which aligns, seals and secures the interior portion of the cable to the plug body and 2) the exterior of the plug body is equipped with adjustable clamps that can be configured to suit various cable diameters and these clamps compress the outer insulation of the cable to secure it to the connector body, preventing the cable from rotating within the plug, or from extending or retracting from the plug body.

2.2 The Pyle-National plug (see Figure 3, right photo & Figure 5, left-top photo) is a large, heavy duty plug designed for use in hazardous environments (but not used in this situation at a hazardous location). The plug uses an internal spring-loaded mechanism that drives the phase pins into the mating receptacle sockets (see Figure 3). Due to the force required to overcome this spring tension, two technicians are required to connect it to a receptacle: one technician threads the plug onto the receptacle and the other technician helps push up and maneuvers the cable to relieve any binding which may occur. Just prior to the SSPF power transfer, the subject cable assembly was used to transfer power at the Operations and Checkout (O&C) Building with the same personnel and equipment without incident . The cable was fabricated and labeled per drawing 79K25959-1 and has been in service since then.

3.0 PROCEDURES AND RESULTS

3.1 The failure analysis was conducted with participation from various members of the NASA Electrical Failure Analysis Lab (see Figure 4). Each team member took different portions of the analysis and performed several tasks such as taking photographs, making video records, inspecting the failed components at the MMSE Canister Rotation Facility (CRF); while other team members interviewed the operators who observed the failure. Mr. Davis collated reports and documents provided by operations personnel. Mr. Ludwig performed field tests on the cable with a Multimeter and Megohm Bridge in order to determine if the 150 foot cable had any short circuit or high resistive type failures.

3.2 Discussions with the contractor indicated that their analysis of the failure was based on the rationale that both cable retention means were compromised at the time of fabrication:

3.2.1 The cable (outside diameter of 1.625 inches) was smaller than the grommet (P/N 38 with an inside diameter of 2.25 inches) provided; therefore, a makeshift inner grommet-extension-filler was fabricated using stripped outer rubber insulation from a scrap cable. The makeshift grommet was irregular on its inside and split apart, to fit inside the grommet of the makeshift assembly (see Figure 5, top right photo). This may have allowed moisture intrusion; and certainly, did not put sufficient pressure against the cable to hold it tightly. Also, if the connector had been used at a hazardous location, it would not provide a proper seal per NEC standards, or any other standard.

3.2.2 The cable clamps were adjusted to a position that would provide the greatest circumferential cable contact area (see bottom-left of Figure 5); however, that configuration did not apply adequate force to keep the cable from rotating. The adjustable clamps could have been reconfigured (see Figure 5, bottom-right), to provide minimal-contact-area (higher-force) upon the cable, but that had not been done for the failed connector assembly.

3.3 Using a Hewlett Packard (HP) Multimeter, the following measurements (see Table 1 below) were taken from a seated position on the CRF floor (see Figure 4). Refer to Figure 3 (left photo) for orientation of the connector measurements. Connector pins were measured from the bottom inner keyway & labeled CW as pins "4" thru "1".

Table 1

Lead Resistance =				0.1455 ohms	
"over range" indicates:				> than 30 megohms	
	Case	4G	3	2	1
Case	X				
4G	0.15 ohm	X			
3	over range	over range	X		
2	over range	over range	over range	X	
1	over range	over range	over range	over range	X

The results indicated that the individual conductors were isolated from one another. This reduced the possibility that a short from one conductor to another had caused the failure and put more emphasis on the connector being the failure mechanism, rather than the cable.

3.4 A Megohm Bridge was also used to verify that the cable was not a part of the failure mechanism. The following measurements (see Table 2 below) were taken (see the Figure 3, left photo, for orientation of the connector measurements). Connector pins were measured from the bottom inner keyway & labeled CW as pin "4" thru pin "1".

Table 2				
	Case	4G	3	2
Case	X			
4G	Short	X		
3	1 teraohm	12 teraohm	X	
2	300 gigohm	12 teraohm	4-5 teraohm	X
1	140-180 gigohm	12 teraohm	4-5 teraohm	10-20 gigohm

Megohm Bridge set with Voltage at 1,000 Volts
Ground and Case Short is normal

The results indicated that at a voltage twice the normal operational characteristics of the cable, would not cause any arc-over from conductor to conductor, nor from any conductor to the case of the attached connector. This was a second verification that the cable was not the cause of the failure.

3.5 With those measurements made, it was determined that the cable was not faulty and with operational concurrence for destructive testing, a short end of the cable (near the failure) was cut off with a hacksaw and taken back to the lab for further analysis. A “Validity Check” was performed back at the laboratory on the field equipment, using three 5% rated resistors, all of which showed out of tolerance. The out of tolerance conditions were confirmed using other calibrated instrumentation, confirming the fields instrument’s operational condition. This provided confidence in the instruments used to take the field measurements.

3.6 The cut-off cable end (see the left half of Figure 6) was photographed along with the connector and the following visual observations were made:

3.6.1 The individual conductor strands of copper had spherical balls of copper (see Figures 6, 7 & 8) near their insulation interfaces and charred burn marks indicating massive overheating caused by an apparent short to all phase conducting wires in the 480 Volt cable connector. It was also noted that the molten balls were above the area of each wire where its individual clamp left witness marks. The probability that all three phases could become shorted together by one loose ground wire is not likely; therefore, a different failure mechanism was sought.

3.6.2 Damage on the smaller “yellow” ground wire (most of the strands were burnt off) (see Figures 6, 7 & 8), as well as, a spherical melted copper ball (see Figures 7 & 8) on its end indicates that the short most likely started with this conductor.

3.6.3 One of the terminal pressure-clamp holes in the blown-off connector had a golden brown coloration, which at first looked like burns from the flashover point of origin and it was assumed that that cavity was the ground wire clamp hole. Further investigation confirmed that it was the ground termination, but the brown area was because the ground connection was designed to have less resistance by using a different metal than the other holes. For instance, the ground pin was smaller by 4/64” (to provide keying) and the male pin was longer than the phase pins so that the ground would make contact first during insertion. Note that the ground clamp hole mechanism was tightened more (extends further into its cavity) than the other clamps. This indicates that the three small ground wires repositioned when they were compressed within the clamp (because they were not mechanically tied together by some means such as twisting, braiding, or crimping). This allowed one of them to be easily extracted by normal cable manipulation.

3.6.4 There are burns inside the connector (see the arrows in Figure 9). Note that the clamp hole to the left of the darker hole, has a large area of damage caused by arcing. Also, each successive counterclockwise clamp hole has less damage.

3.7 The cable end was X-rayed (see Figure 7). The X-ray images depicted that the melted coppers balls were concentrated near the intersection of insulation to bare-copper. One spherical ball was on the end of the yellow ground conductor suggesting that the bottom of the conductor had loosened and contacted the conductor strands of one of the 480 volt phase wires. Also, since it was the most heavily damaged, it indicated that this was the conductor where the major shorting flashover was initiated. What followed was an observed “flashover” that caused the cable to physically separate from its connector that was attached firmly to the wall.

3.8 Closer analysis (see Figure 10) of the individual conductors of the cut-off cable end, revealed that each conductor had been cut off at unequal lengths and that the insulation of each conductor had each been stripped off at an unequal length (see Table 3 below).

Table 3	
Distance Measurements made on the cut-off (failed) end of cable C1	
Depth Black wire was stripped	1.375 inch
Delta between Black and White stripping	0.250 inch
Depth White wire was stripped (jagged)	1.500 inch
Delta (max) between White and Red stripping	0.375 inch
Depth Red wire was stripped	1.391 inch
Delta between Black and Red stripping	0.250 inch
Depth 1st Green ground wire was stripped	1.672 inch
Depth 2nd Green ground wire was stripped	1.375 inch
Depth Yellow ground wire was stripped	1.500 inch
Depth of Clamp holes	1.688 inch
Depth of clamp holes plus "star" barrier	2.188 inch
Minimum to Maximum of striped wires	2 inches
Depth overall Cable Insulation Stripped from tip of wires	6 inches
Depth from clamp hole to top of grommet in cable assembly	6.641 inch
Depth of grommet	1.141 inch
Depth that grommet surface did not contact surface of cable	0.500 inch

When the cable wires (see Figure 11, top photo) are bundled together tightly, or arranged approximately as they would be inside the connector (see Figure 11, bottom photo) the disparity of the uneven stripping is quite notable. This is because, although the length of the stripping of each wire varied by just 19/64 ths of an inch, the ends of the wires were cut off at different lengths. It can be seen (comparing Figure 11 with the Table 3 above) that when the longest green ground wire is bottomed out in a clamp hole that:

3.8.1 the bare copper is just the length of the clamp hole depth,

3.8.2 the other wires could not be bottomed out, since they were trimmed bare of insulation close to the length of the clamp hole depth (see table). Subsequently bare copper would be exposed above the top of the clamp hole and possibly above the “star” barrier, if they had been loose, as was one ground wire.

3.8.3 the white phase voltage wire (the one with the most molten depositions) would be in the cavity above the clamp retainer mechanism and just below the top of the barrier. Therefore, if a phase wire were not pushed in as much as possible or if it had slipped out a little (during rotation manhandling of the connector attachment) then it would be exposed where a loose ground wire could come into contact with it and generate a catastrophic short circuit.

3.9 In order to provide additional troubleshooting of the flashover failure, the wall mounted Receptacle Assembly (P/N GB-B728-31SSL-BL) was removed, the internal cables were cut off and the receptacle transported to the Electronic Failure Analysis Lab for analysis (see Figure 12). No visible damage was observed, but looking down into the female connector, a golden brown wall (similar to the connector cavity that was assumed to be the cavity or hole where the yellow ground wire was vaporized) was evident. Looking thru the lower connector opening (see right photo of Figure 12), a ground lug is visable, which is traced to the female receptacle cavity labeled 4G. This verifies that that pin was the ground terminal. No damage was noted to the female terminal and the corresponding terminal in the male connector. The receptacle covers were removed and the individual inside wires were visually inspected by the investigator and customer. No indications of any damage, or any suspect conditions were noticed. Therefore, further investigation of this part was not deemed necessary.

3.10 The "Vantage Technology GB & GD Series Assembly and Terminating Instructions" (instructions normally supplied with the connector parts during shipping) were reviewed (see Figure 13) and it also verified that the ground lug was pin 4. However, discrepancies were noted:

3.10.1 On page 2, "Step 3 – CABLE JACKET & WIRE STRIPING" (see Figure 12), it states, "STRIP CABLE JACKET, **3"** AS SHOWN"; but, the jacket was stripped twice as far (**6"**) from the wire ends.

3.10.2 Taking measurements on the failed connector (from the bottom of a clamp connector hole to the top of the grommet), reveals that this distance is 6.641 inches. The grommet height is 1.141 inch. Since the cable was stripped back 6 inches, there was 0.500 inch of inside grommet surface that had no outer cable sheath to grip. This was another reason that the cable could easily slip, because its cable retention design methodology was compromised.

3.10.3 In the same step, the "NOTE" states, "The cable should be free of groves or ridges in the area where the cable grommet seats on the cable. Smooth cable O. D. so that the cable grommet fits snugly 360 [degrees] on the cable. Also be sure that the correct grommet size has been ordered to fit cable." Looking at the makeshift grommet assembly (see Figure 5, top-right photo), it can be seen that the "correct grommet size" was not ordered, and that there was no way that the ragged inner surface of the makeshift "grommet fits snugly 360 [degrees] on the cable." In fact, the grommet could slip both relative to the cable and relative to its outside manufactured (wrong size) grommet; as well as, not providing anything close to a "snug fit. In fact, these added-up fabrication-construction deficiencies, badly compromised the cable retention design methodology.

3.11 The connector was disassembled and it was noted that there were debris fields of spherical copper balls with the metal embedded (by force) into the sides of the inner cavity. The greater number of small "projectile" debris (see Figure 14, top photo) can be seen in the area of pin 4G and pin 1 to its left. These are the clamp holes for the pins where the initial shorting is assumed to have taken place. See also, the photo in Figure 9 that better shows the greater burn damages in that same area. There is a larger spherical copper ball embedded in the side (beside pin 3) of the inner connector cavity (see Figure 9, below the smallest arrow). If the ball had been deposited by a flash from the major arc burn area, then it would have had to pass thru two wires. Most likely, this sphere was deposited by ionization of the copper ground conductor.

3.12 The "Solid Rocket Motor (SRM) Payload Canister Transporter 60 HZ Electrical Power System (EPS) Cable Installation" Drawing, 79K25259, was retrieved from the Kennedy Electronic Drawing System (KEDS) web site at: http://wwwde.ksc.nasa.gov/keds/keds.htm It consists of 3 sheets and one EO and is electronically labeled as: "n25959a0.001, n25959a0.002, n25959a0.003 and r25959a0.001." and consists of sheets entitled "Physical Layout & Notes; Cable List Layout & Details: Cable Schedule; and an Engineering Order (EO) concerning Cable C-2." This drawing was reviewed and it was noted that it listed pin 1 as "phase C," pin 2 as "phase B," pin 3 as "phase A" and pin 4 as "ground." It also identifies Cable C-1 as the "EPSF to Facility" cable and states that it should be a 150 foot cable rated for 480V 3 phase, at 200 Amps, Type G, with 3 conductors (# 2/0) plus a ground. There are no other references to any assembly drawing, but flag note #6 identifies it as "**Cable Assembly is Government Furnished**."

3.13 From discussions with the connector manufacturer and with operators, additional facts were revealed. The hazardous connector was used because there were many left over after other facility modifications. The cable was chosen because it had a smaller diameter and was lighter and more flexible. The outside cable markings were: "2/0-3 Type G-GC 2000V". Type G is "flexible" and "GC" stands for "Ground Check" (used in the underground mining industry to remotely verify ground continuity thru monitoring of the yellow ground wire). The design engineer from the connector manufacturer, suggests stripping the ground wires twice longer than required, twisting them together and cutting them to the proper insertion depth. Then, he suggests cutting and re-striping all other cable wires to the proper depth to ensure that all wires bottom out in the clamp holes (so that no bare wire extends above the pressure clamps). The manufacturer suggested an alternative workaround of using available pin inserts which can allow crimping of the wires.

3.14 From the data derived above, a reasonable postulation was developed:

3.14.1 From the damage to the small yellow ground wire, it was obvious that this was the ignition point and that part of the wire had been vaporized as a result of the initial short circuit.

3.14.2 From the debris fields of small specs of molten copper and other metal deposited on the sides and base of the inner connector, and melted balls of copper on the surfaces of the wires that were exposed above their pressure-clamp coverings and within the connector housing (either above or slightly below the open cavity next to the “star barrier”), it was obvious that the vaporization was so intense that the metal was deposited thru an ionization cloud of molten metal. This explains the reason (see paragraph 3.6.1) that all phases, not just one, appeared to be shorted.

3.14.3 The arcing between equal potential surfaces (described in 3.6.4 above) can be explained as arcing between the wires and the connector, as the wires were ejected from the cavity under current load. The most arcing can be seen (see Figure 9) next to the clamp cavity (pin 1) where the ground wire first shorted out to the first phase voltage wire. This shorting caused an ionization and the resulting vaporization, melting, embedding and deposition of/to the other phases would have lasted very briefly: so briefly, that the other two phases did not have as much time to draw the current that was drawn by the initial phase wire short circuit. This effect caused less damage to those two termination holes as the wires were ejected from the expanding ionization cavity.

4.0 DISCUSSION

4.1 The failure was most likely caused by faulty fabrication techniques:

4.1.1 The makeshift grommet’s irregular shape did not provide proper cable tightness to keep it from rotating inside the connector.

4.1.2 Exterior cable clamps were not configured for optimal retention of the cable, also allowing it to rotate with the connector body.

4.1.3 The cable was stripped improperly, so that even a good grommet would not have adequate surface area contact with the connector.

4.1.4 The individual conductors of the cable were not cut off at an equal length and their insulation had not been stripped off at an equal length. Proper installation would have prevented the wires from extending above the internal connector barrier and becoming exposed in an open internal connector space (between the wire and barrier, or just above the “star” barrier).

4.1.5 The three small grounding conductors were not mechanically attached together, allowing the pressure plates to exert a clamping force which spread apart the separate conductors and allowed one to later come loose. Fixes are suggested in paragraph 3.13; but, a better selection of cable wires (i.e. the use of: 3 wires plus 1 ground conductor, not: 3 wires plus 3 ground conductors) would have eliminated this particular problem.

4.2 All above poor assembly/construction procedures and the incorrect following of Assembly Drawing instructions, resulted in several failure mechanism starting points that overall combined to create the failure.

4.3 The five inadequacies (refer to paragraph 4.1) in the cable assembly construction, allowed normal manhandling to apply stress to the cable conductors; which caused them to work loose from their pressure clamp terminations and become free to reposition inside the connector and to contact other bare copper conductors that were extended above the internal barrier strip: because they were loosened and/or improperly trimmed.

5.0 CONCLUSION

After the closing of a circuit breaker, electrical arcing was caused by two conductors contacting each other after one came loose (because of twisting and normal manhandling of the cable assembly) during plug connection to the receptacle. The arcing caused a “flashover” that vaporized part of the loose ground wire and caused an ionization cloud of copper to be developed. The cloud deposited molten balls of copper on the other wires that were above the clamp covered surfaces and on the inner open surfaces of the connector cavity. This ionization cloud caused a additional short circuit to be developed on all phase wires, ionizing the chamber further, expanding with such force that it caused the cable assembly to be ejected out of the back end of the connector (that was firmly attached to the wall receptacle). The separation of wires from their clamp assemblies caused arcing between each wire and its corresponding clamp assembly surface, in proportion to the time the shorts occurred and in proportion to the resulting load that was drawn by each wire.

6.0 RECOMMENDATIONS

Elimination of the fabrication inadequacies (see paragraph 4 Discussion) should eliminate the causes of the failure mechanism starting points. In other words: cable construction, in accordance with proper fabrication standards and in accordance to good design specifications, would prevent a similar failure from occurring.

EQUIPMENT: HP Multimeter, Calibration number Z51058
(Cal due on 01/Mar/02)
Megohm Bridge, Calibration number C5395
(Cal due on 07/Jan/02)

RELATED DOCUMENTATION:

Previously released reports: "Evaluation of the transporter cable electrical flashover at the SSPF" - 27 July 2001.
Disposition form M. M. P70-0555-P074.

Drawing numbers: 79K25959-1, SRM Payload Canister Transporter 60 Hz Power EPS Cable Installation

ASTM or other standards: Vantage Technology GB & GD Series Assembly and Terminating Instructions.

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Figure 1

Cable C-1 in its entire length, with undamaged Russell-Stoll Plug attached and without missing Pyle-National Plug that was separated from the cable assembly, due to force of flashover at time of failure. Magnification: oblique view.

Figure 2

Cable end that Pyle-National plug was blown off of. Note that strands of yellow-looking ground plug (left-most photo) was the same thickness as the two other green ground conductors (all three previously inserted into one plug terminal clamp), but most of its strands are burnt off and missing.   Conductors show burns on insulation indicating that arc-over occurred which was observed as a “flashover.” Magnification, left photo: oblique view; right photo: 0.28X.

Figure 3

Connectors from both ends of failed Cable. Female Connector in left photo was tested in Canister Rotation Facility (CRF). Pins, from bottom inner key, were labeled pins ”4” Clockwise (CW) thru “1” in write-up. Blown-off Male connector is shown in the right photo. Magnification: oblique views.

Figure 4

Photo documentation and field resistance checks (case-to-pin and pin-to-pin) of the cable end, at the Canister Rotation Facility. Magnification: oblique view

Figure 5

Pyle-National plug is shown with adjustable clamps on its' far right side (top-left photo). The top-right photo shows "manufactured" grommet and "makeshift" (inside) grommet. This was one obvious reason that the cable was not held tightly in the connector. Magnification top left: 0.18X, right: oblique view.

The second obvious reason that the cable was not held tightly was the configuration of the adjustable clamps. The bottom left photo shows the Pyle-National plug's adjustable clamps as they were assembled at the time of failure. The bottom right photo shows the adjustable clamps configured for an appropriate cable tightness (the desirable configuration with the screw assembly lengths chosen) to help prevent a similar future failure. Magnification: 0.43X, in both bottom left and bottom right photos.

Figure 6

Cable cut off (left photo), for laboratory analysis. Magnified photo at right, shows that strands of copper had evidence of overheating / melting. Magnification: left photo, oblique view. Magnification: 1.82X, right photo.

Figure 7

X-rays show melted coppers balls were concentrated near the insulation on all except the most damaged ground conductor which obviously came loose: causing shorting and melting to occur. Magnification: oblique views

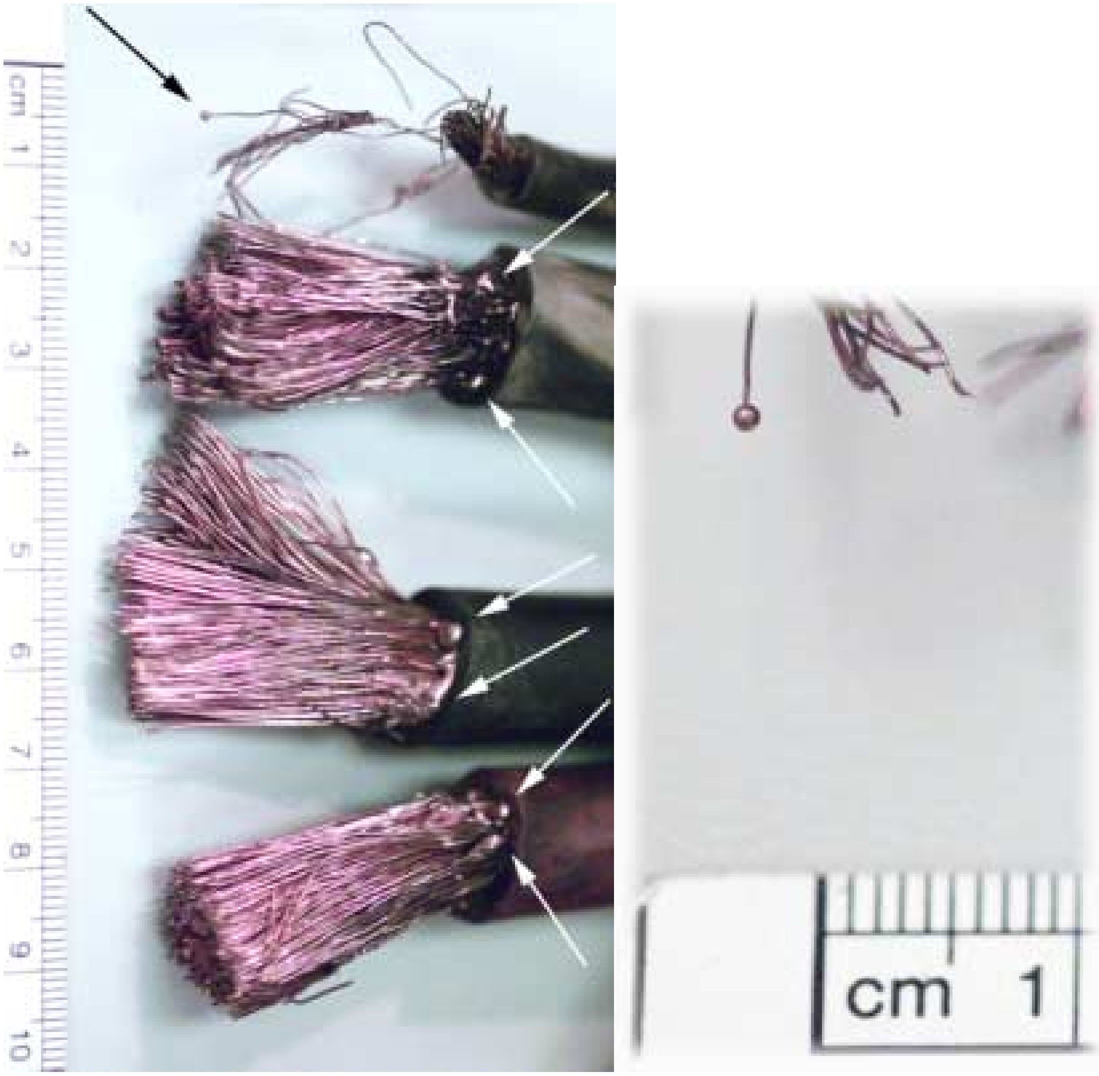


Figure 8

Arrows indicate the locations of spherical balls of copper indicating massive overheating caused by an apparent short to each phase of the 480 Volt cable. Damage (left photo) & spherical melted copper ball (magnified on right photo) on small ground wire (most of the strands were burnt off) indicates that one of the three smaller ground conductors received the most damage from shorting (indicating that the short started on this conductor). It is assumed that this wire came out from it's clamped terminal and contacted another loose terminal, when the cable was twisted; thereby, creating the failure. Magnification: 1.37X, left photo. Magnification: 3.75X, right photo.

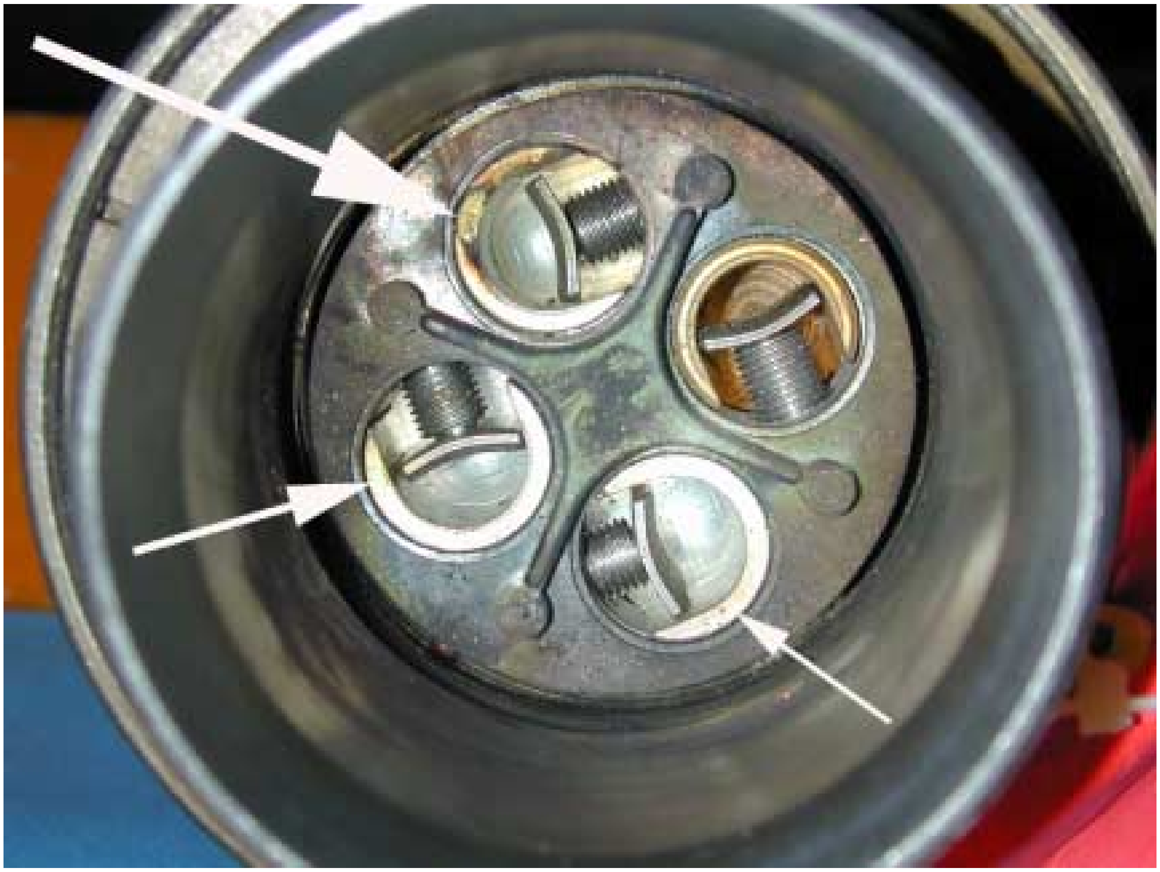


Figure 9

Photo shows terminal clamps in blown-off connector. Notice that one of the pressure clamp holes has a brown coloration (a different material). This pin is the ground pin hole that probably was the flashover point of origin. The Star in the middle is an insulating barrier that should have prevented a short circuit if the wires were properly stripped, or not loosed, where they were above the barrier mechanism. Notice the damage caused by current arcing (see arrows). Magnification: 1.10X.

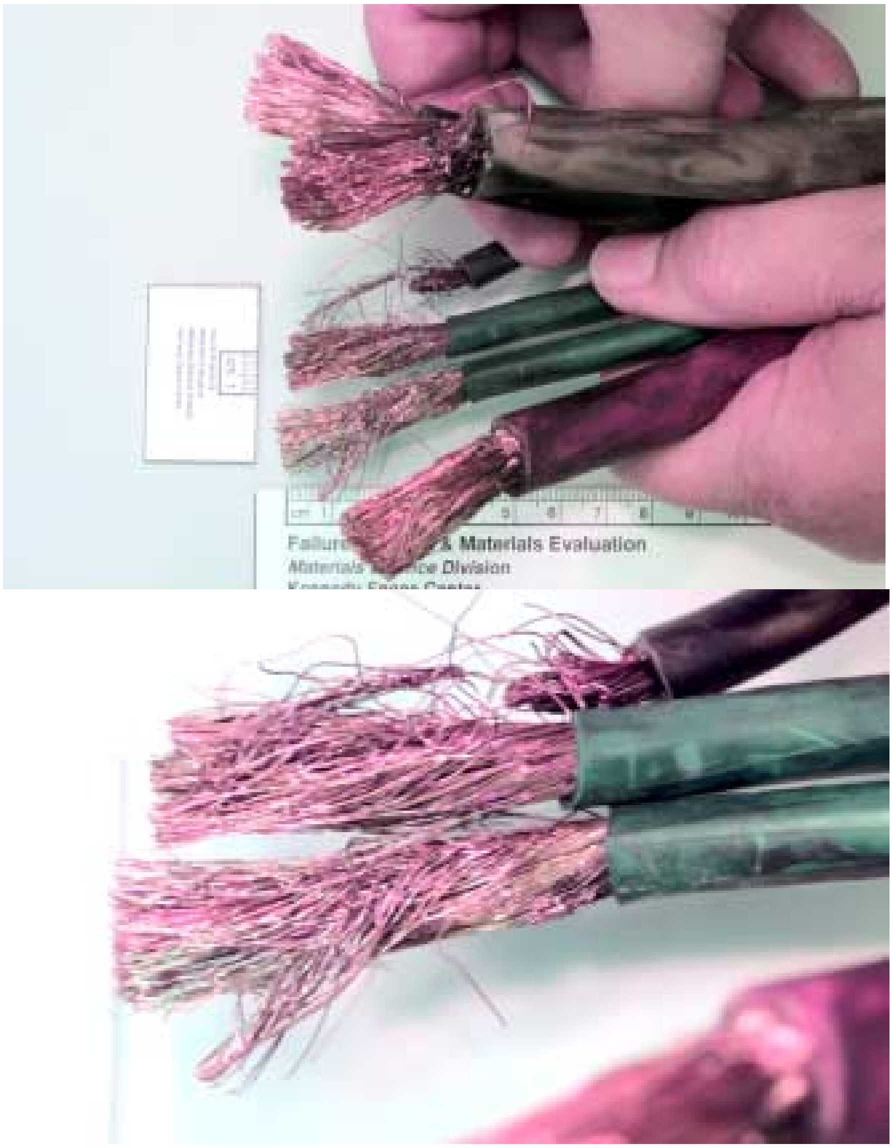


Figure 10

Photos depict that the individual wires of each conductor had not all been cut off at an equal length. They also depict that the insulation had not each been stripped off at an equal length. If properly cut to length and if properly stripped of insulation at equal lengths, then there would be less of a chance of shorting if one of the conductors were pulled loose. Also, the three small grounding conductors should have been mechanically locked together (possibly by twisting, braiding or crimping) to prevent one of them from pulling loose. Magnification: 0.60X, top photo, 1.56X, bottom photo.

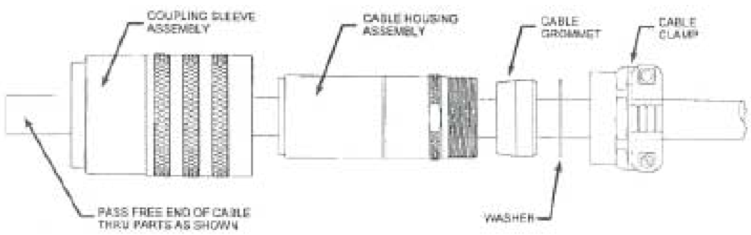
Figure 11

When the internal cable wires (top photo) are bundled together tightly, or arranged approximately as they would be inside the connector (bottom photo) the disparity of the uneven stripping is quite notable. Refer to discussion in paragraph 3.8. Magnification: 1.13X in top photo, 1.11X in bottom photo.

Figure 12

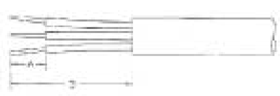
The wall mounted Receptacle Assembly was not damaged and is shown here only for information. Looking thru the bottom connector assembly opening, you can see the grounding method and trace the ground cable to pin 4G of the receptacle's female connector that was attached to the male connector that had an internal failure. Magnification left photo: oblique view, right photo: 0.38X.

STEP 2 - ASSEMBLY OF ADAPTER COMPONENTS



STEP 3 - CABLE JACKET & WIRE STRIPPING

STRIP CABLE JACKET 3" AS SHOWN. SELECT "A" FROM TABLE TO CORRESPOND WITH CONNECTOR RATING AND STRIP CONDUCTORS. THE CONNECTOR'S RATING CAN BE FOUND ON THE PLUG'S NAMEPLATE.



RATING (AMPS)	DIM. A (INCHES)
30	13/16
60	1 11/32
100	1 3/8
200	1 15/32

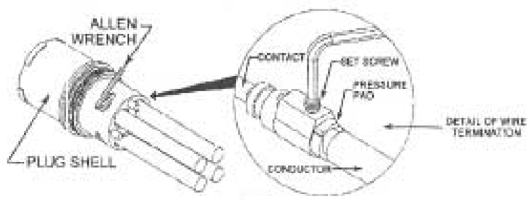
NOTE: The cable should be free of grooves or ridges in the area where the cable grommet seats on the cable. Smooth cable O.D. so that the cable grommet fits snugly 360° on the cable. Also, be sure that the correct grommet size has been ordered to fit cable.

STEP 4 - TERMINATING CONDUCTORS

TERMINATE CONDUCTORS (SEE DETAIL) THRU NUMBERED INSULATION CAVITIES PER TABLE BELOW. TIGHTEN SET SCREW TO VALUE PER TABLE.

CAVITY NO. AND WIRE COLOR					
	1	2	3	4	5
2W.3P.	BLACK	WHITE	GREEN		
3W.4P.	BLACK	WHITE	RED	GREEN	
4W.5P.	BLACK	WHITE	RED	GREEN	ORANGE

RATING (AMPS)	TORQUE (IN-LB)
30	26
60	26
100	70
200	120



NOTE: Do not remove insert from plug shell.

Page 2

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Figure 13

Shown above, is page 2 of the Installation Guide that was supplied with the connector components (refer to comments in paragraph 3-10 concerning connector and cable fabrication irregularities).

Figure 14

These photos show the debris fields of spherical copper balls on the sides of the inner cavity. Note the greater number of small debris (top photo) in the area of pin 4G (the darker clamp hole) and pin 1 to its left. Note also, that there is a larger spherical copper ball embedded in the side (above pin 3) of the inner connector cavity. See paragraph 3.13.2 discussion. Magnification: oblique views